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Influence of NAA and Zinc Sulphate on Fruiting Parameters and Marketable Yield of Litchi (*Litchi chinensis* Sonn.) cv. Rose Scented

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

This experiment was conducted in 2022 and 2023 at the Horticulture Garden, Department of Fruit Science, C.S. Azad University of Agriculture and Technology, Kanpur (U.P.). On three replications with sixteen treatments, the Factorial Completely Randomized Design (CRD) was used, four levels of NAA (0, 25, 50, and 75 ppm), zinc sulphate (0, 0.2, 0.4, and 0.6 percent), and their combination were sprayed twice, on January 28 and March 16 of each year, respectively, before flowering and fruit setting (at pea stage). This study examines the effects of NAA and ZnSO4 on litchi cv. Rose scented for enhanced flowering, and high yield of improved quality fruits of litchi. According to the findings, the treatment with NAA 50ppm and 0.4% zinc improved fruiting-like; fruit set per panicle (258.90 and 259.41), fruit count before the second foliar spray at the pea stage (45.81 and 49.19), fruit count at pit hardening stage (39.15 and 38.70), fruit count at ripening stage (22.80 and 23.44) with a decreased fruit cracking (2.14 and 2.10) and higher yield of marketable fruits (78.34 and

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78.29 kg/plant). The consequences of the medium concentration also showed the highest physical parameters of fruit length (3.57 and 3.60 cm), largest fruit diameter (3.22 and 3.20 cm) and fruit weight (20.12 and 22.28 g). It was concluded that the application of NAA and zinc had a non-significant impact on fruiting and quality of litchi, resulting in maximum fruit set and retention and yield-related characteristics like fruit weight that ultimately led to an increase in the yield per plant.

Keywords: Litchi; NAA; ZnSO4; fruiting parameters; marketable yield.

1. INTRODUCTION

In India, litchi was introduced through Burma in the 18th century and quickly spread to other countries. 91% of the world's litchi production is produced in India and China, however it is primarily sold locally. In India, 98000 ha of land are used to produce 724000 MT of litchi annually [1].

The litchi (*Litchi chinensis* Sonn.) is the most important sub-tropical evergreen tree which is a member of the family Sapindaceae. The names "Summer Sweet" and "Queen of Fruits" are also used to refer to litchi. In terms of botany, the mature fruit of the litchi is a nut, and the juicy aril is the edible part [2-4]. It is sour and quite sweet when dried. It is a good source of minerals like magnesium, iron, calcium, copper, phosphorous, and potassium as well as carbohydrates, vitamins, and other nutrients. It is transformed into juice, wine, pickles, jam, jelly, ice cream, and yogurt. The term "litchi nut" refers to dried litchi, which has a raisin-like flavor [5].

Globally, Southeast Asian countries including China, India, Vietnam, and Thailand are the largest producers of litchi, but the fruit is also famous in Africa. Of the total world production of litchi, India is the second largest producer after China. It is grown abundantly in the sub-mountain districts of Uttar Pradesh i.e., Saharanpur and Muzaffarnagar [6-9].

It is available in the market from May through June, when there are many other fresh fruits available. However, despite the availability of different fruits in the market, the demand for fresh litchi is still very high due to its unique taste, flavor and color.

Over the years, plant growth regulators (PGRs) and micronutrients have been systematically used to increase the maximum and long-term economic benefits of litchi production by modifying the behavior of fruit or fruiting trees. The yield and quality of litchi fruit are positively influenced by trace factors and plant growth regulators. PGR application leads to increased flowering, fruit set and fruit retention. The cell sap supply pathway to the fruit is severed by the formation of the dermis and the thin cork cells gradually separate, resulting in fruit drop. Early researchers reported that gibberellin affects both cell division and expansion (Megu et al*.,* [10] Nand et al*.* [11]. Adjuvants such as naphthalene acetic acid (NAA) greatly influence plant growth; However, their effectiveness depends on application, time and concentration.

Micronutrients have an important function in improving the growth, yield and quality of litchi. The metabolic activities of plants are highly dependent on zinc [12-14]. Zinc mainly acts as a metal activator of enzymes such as dehydrogenase (pyridine nucleotide, glucose - 6 phosphodiesterase, carbonic anhydrase, etc.). Tryptophan, a precursor of IAA, is highly dependent on zinc for synthesis, and is involved in the absorption and retention of water in the plant body. Fruit cracking and splitting also take place during the fruiting season when extremely dry and harsh winds blow. The cracked fruit rots quickly and has no selling value. The problem of cracking is considered the main obstacle to the expansion of the litchi growing area.

2. MATERIALS AND METHODS

The well-established healthy and uniform trees of the litchi cultivar Rose Scented were selected for the experiment, located at Horticulture Garden, Department of Fruit Science, Chandra Shekhar Azad University of Agriculture & Technology Kanpur was selected for the present investigations during 2022 and 2023. The trees were about 30 years old but properly maintained. During this course of the investigation the whole orchard was kept under clean and uniform cultivation. The plant growth regulator and mineral nutrients were sprayed on the tree. Factorial Completely Randomized Design was used with three replications and sixteen treatments viz., four levels each of NAA (0, 25, 50 and 75ppm) and zinc (0, 0.2, 0.4 and 0.6%) and their combination were sprayed twice. The first spray was applied before flowering (28/01/2022) and the second sprays at the pea stage of fruit was applied on date (16/03/2022) with a sprayer with having very fine nozzle. The same spraying schedule was also followed on 26/01/2023 and 22/03/2023. Care was taken to give uniform spray all over the branch.

The number of fruits per panicles, the number of fruits set, fruit drop, fruits retention, fruits cracked, marketable yield and juice content. The total soluble solids (TSS) were taken with an Erma hand refractometer.

3. RESULTS AND DISCUSSION

3.1 Fruit Count before Second Foliar Spray at the Pea Stage

Interactive effect of NAA and Zinc was found to be non-significant, treatment of N_2Z_2 reported maximum (45.81 and 49.19) fruit count before foliar spray at the pea stage closely followed by treatment N_2Z_3 (45.11 and 48.73). The minimum (35.53 and 38.46) fruit count before foliar spray at the pea stage was presented with control (N_0Z_0) during both the years of experiments. The chemical significantly increased the fruit count as compared to control however, the highest fruit count was obtained with the application of zinc sulphate and NAA. These results corroborate the work of Saraswat et al*.* in litchi and Kumar et al*.* [15] in mango.

3.2 Fruit Count at the Pit Hardening Stage

The fruit count at pit hardening was found to be considerably non-significant, the highest fruit count at the pit hardening stage was induced by the N_2Z_2 treatment (39.15 and 38.70), closely followed by the N_2Z_3 treatment (38.22 and 38.22). The control (N_0Z_0) was shown to have the lowest fruit count (30.90 and 30.70) at pit hardening in both of the trial years. It has long been known that applying plant bio-regulators such as NAA can encourage fruit set in pears. These outcomes also agree with the conclusions of Sinha et al*.*, Pandey et al*.* and Sharma et al*.* in Litchi.

3.3 Fruit Count at the Ripening Stage

Interactive effect of NAA and Zinc was found to be non-significant, treatment of N_2Z_2 reported maximum (22.80 and 23.44) fruit count at the ripening stage closely followed by treatment N_2Z_3 (22.13 and 23.12). The minimum (15.68 and 17.17) fruit count were recorded under control (N_0Z_0) during both the years of experiments. The chemical significantly increased the fruit count as compared to control however, the highest fruit count was obtained with the application of NAA and zinc sulphate with medium concentrations. These results are aligned with the work of Kumar et al*.* (2018) and in mango Saraswat et al*.* in Litchi.

3.4 Fruit Set Per Panicle

Correlative influence of NAA and Zinc was found significantly maximum under treatment of N_3Z_3 (258.90 and 259.41) fruit set closely followed by treatment N_2Z_3 (256.33 and 257.40). The minimum (212.50 and 214.51) fruit set were presented with control (N_0Z_0) during both years of experimentation. The chemical significantly increased the fruit set as compared to the control however, the highest fruit set was obtained with the application of 0.4 per cent zinc sulphate + 50 ppm NAA. It has been early reported that fruit set in pear can be promoted with the application of plant bio-regulators like NAA. These results are also in conformity with the findings of Saraswat et al*.* in litchi and Pandey et al*.* in ber.

3.5 Number of Cracked Fruits at Harvesting

The collective impact of NAA and Zinc was found to be non-significant, treatment of N_2Z_2 induced minimum (2.14 and 2.10) number of cracked fruits at harvesting closely followed by treatment N_2Z_3 (2.33 and 2.28). The maximum (5.54 and 5.68) Number of cracked fruits at harvesting was presented with control (N_0Z_0) during both experiments. The spraying of NAA was found more effective than $ZnSO_4$. It is well known that zinc spray regulate auxin in the plants which might have increased the synthesis of tryptophan and indirectly also regulated water relations in plants, zinc in combination with NAA affect the activity of cellulase, thereby maintaining cell wall rigidity reduced the fruit cracking. These results are by the reports of in litchi. The present findings are in agreement with the report of Saraswat et al*.*, Kumar et al*.* (2001), and Gupta et al*.* [16] in litchi. It is commonly known that zinc spray controls auxin in plants, which may have enhanced tryptophan production. Zinc spray also indirectly controls plant water relations. Auxin application may have raised the cell sap's osmotic pressure, caused water absorption and lowered the percentage of fruits that fracture.

Table 1. Effect of foliar sprays of NAA, Zinc and their interactions on fruit at the pea stage, pit hardening stage and ripening stage

Parameter	**Doses**	**Zinc % (B)**									
	NAA ppm (A)	**2022**					**2023**				
		B_0 Control	**B_1 0.2**	**B_2 0.4**	**B_3 0.6**	**Mean A**	**B_0 Control**	**B_1 0.2**	**B_2 0.4**	**B_3 0.6**	**Mean A**
Fruit Count at second foliar spray at pea stage	A_0 Control	35.533	36.427	37.770	38.590	37.080	38.463	39.277	40.800	41.160	39.925
	A_1 25	39.097	40.007	40.740	40.880	40.181	42.067	43.147	44.440	44.513	43.542
	A_2 50	44.170	44.997	45.817	45.110	45.023	47.270	48.387	49.197	48.730	48.396
	A_3 75	41.793	42.740	42.930	43.683	42.787	45.073	45.690	46.030	46.903	45.924
	Mean B	40.148	41.043	41.814	42.066		43.218	44.125	45.117	45.327	
	Factors	CD at 5%	SE (d) ±	SE (m) ±			CD at 5%	SE (d) ±	SE (m) ±		
	A	1.131	0.553	0.391			1.134	0.554	0.392		
	B	1.131	0.553	0.391			1.134	0.554	0.392		
	A X B	NS	1.105	0.782			NS	1.109	0.784		
Fruit Count at pit hardening stage	A_0 Control	30.903	31.537	31.980	33.100	31.880	30.703	31.227	32.190	32.850	31.743
	A_1 25	33.137	33.737	34.850	34.770	34.123	33.377	33.637	34.740	34.733	34.122
	A_2 50	37.330	38.187	39.157	38.220	38.223	37.110	37.937	38.707	38.220	37.993
	A_3 75	35.213	36.240	36.590	37.333	36.344	35.213	35.940	36.290	36.933	36.094
	Mean B	34.146	34.925	35.644	35.856		34.101	34.685	35.482	35.684	
	Factors	CD at 5%	SE (d) ±	SE (m) ±			CD at 5%	SE (d) ±	SE (m) ±		
	A	1.145	0.559	0.396			1.139	0.557	0.394		
	B	1.145	0.559	0.396			1.139	0.557	0.394		
	A X B	NS	1.119	0.791			NS	1.114	0.788		
Fruit Count at Ripening stage	A_0 Control	15.680	16.580	16.857	17.240	16.589	17.170	17.850	18.240	18.880	18.035
	A_1 25	17.850	18.020	18.340	18.873	18.271	19.070	19.340	20.953	21.140	20.126
	A_2 50	21.517	21.720	22.807	22.130	22.043	22.760	22.933	23.447	23.120	23.065
	A_3 75	19.957	20.057	20.353	21.287	20.413	21.457	21.647	21.920	22.330	21.838
	Mean B	18.751	19.094	19.589	19.883		20.114	20.443	21.140	21.368	
	Factors	CD at 5%	SE (d) ±	SE (m) ±			CD at 5%	SE (d) ±	SE (m) ±		
	A	0.263	0.128	0.091			0.498	0.244	0.172		
	B	0.263	0.128	0.091			0.498	0.244	0.172		
	A X B	NS	0.257	0.182			NS	0.487	0.344		

Table 2. Effect of foliar sprays of NAA, Zinc and their interactions on fruit set per panicle, fruit cracking and marketable yield

Parameter	Doses	Zinc % (B)									
	NAA ppm (A)	2022					2023				
		B_0 Control	B_1 0.2	B_2 0.4	B_3 0.6	Mean A	B_0 Control	B_1 0.2	B_2 0.4	B_3 0.6	Mean A
Fruit Set per panicle	A_0 Control	212.503	215.417	219.680	225.540	218.285	214.513	217.387	220.380	224.590	219.218
	A_1 25	228.207	232.567	236.100	236.507	233.345	227.107	231.517	233.700	235.223	231.887
	A_2 50	250.430	253.727	258.907	256.330	254.848	251.500	255.327	259.417	257.400	255.911
	A_3 75	240.623	242.480	245.710	248.763	244.394	242.323	244.360	246.750	249.863	245.824
	Mean B	232.941	236.048	240.099	241.785		233.861	237.148	240.062	241.769	
	Factors	CD at 5%	SE (d) ±	SE (m) ±			CD at 5%	SE (d) ±	SE (m) ±		
	A	1.121	0.548	0.388			1.171	0.572	0.405		
	B	1.121	0.548	0.388			1.171	0.572	0.405		
	A X B	2.243	1.096	0.775			2.342	1.144	0.809		
Fruit Cracking	A_0 Control	5.540	4.620	4.513	4.320	4.748	5.683	5.210	4.830	4.260	4.996
	A_1 25	3.967	3.840	3.770	3.520	3.774	4.077	3.873	3.660	3.447	3.764
	A_2 50	2.677	2.593	2.140	2.330	2.435	2.537	2.330	2.100	2.280	2.312
	A_3 75	3.410	3.280	3.170	2.763	3.156	3.223	3.107	2.980	2.770	3.020
	Mean B	3.898	3.583	3.398	3.233		3.880	3.630	3.393	3.189	
	Factors	CD at 5%	SE (d) ±	SE (m) ±			CD at 5%	SE (d) ±	SE (m) ±		
	A	0.080	0.039	0.027			0.075	0.037	0.026		
	B	0.080	0.039	0.027			0.075	0.037	0.026		
	A X B	0.159	0.078	0.055			0.151	0.074	0.052		
Marketable Yield per tree	A_0 Control	46.013	48.727	51.570	54.060	50.093	48.353	50.477	52.980	54.250	51.515
	A_1 25	58.777	61.157	63.630	64.110	61.918	61.637	63.807	64.890	65.490	63.956
	A_2 50	71.500	73.957	78.347	76.430	75.058	74.670	75.777	78.297	77.040	76.446
	A_3 75	66.773	67.290	68.510	70.113	68.172	68.753	70.040	70.550	72.923	70.567
	Mean B	60.766	62.783	65.514	66.178		63.353	65.025	66.679	67.426	
	Factors	CD at 5%	SE (d) ±	SE (m) ±			CD at 5%	SE (d) ±	SE (m) ±		
	A	1.120	0.547	0.387			1.120	0.547	0.387		
	B	1.120	0.547	0.387			1.120	0.547	0.387		
	A X B	NS	1.095	0.774			NS	1.094	0.774		

Table 3. Effect of foliar sprays of NAA, Zinc and their interactions on Fruit length, diameter and weight

Parameter	Doses	Zinc % (B)									
	NAA ppm	2022					2023				
	(A)	B_0 Control	B_1 0.2	B_2 0.4	B_3 0.6	Mean A	B_0 Control	B_1 0.2	B_2 0.4	B_3 0.6	Mean A
Fruit length	A_0 Control	2.540	2.680	2.873	2.950	2.761	2.620	2.743	2.830	2.897	2.773
	A_1 25	3.083	3.180	3.253	3.280	3.199	2.947	2.980	3.053	3.073	3.013
	A_2 50	3.470	3.517	3.577	3.547	3.528	3.420	3.447	3.600	3.520	3.497
	A_3 75	3.333	3.350	3.410	3.440	3.383	3.087	3.110	3.183	3.330	3.178
	Mean B	3.107	3.182	3.278	3.304		3.018	3.070	3.167	3.205	
	Factors	CD at 5%	SE (d) ±	SE (m) ±			CD at 5%	SE (d) ±	SE (m) ±		
	A	0.076	0.037	0.026			0.065	0.032	0.023		
	B	0.076	0.037	0.026			0.065	0.032	0.023		
	A X B	NS	0.074	0.052			NS	0.064	0.045		
Fruit Diameter	A_0 Control	2.280	2.460	2.520	2.540	2.450	2.400	2.563	2.650	2.670	2.571
	A_1 25	2.630	2.750	2.823	2.850	2.763	2.700	2.720	2.730	2.797	2.737
	A_2 50	3.140	3.160	3.220	3.207	3.182	3.020	3.050	3.200	3.080	3.088
	A_3 75	2.940	3.023	3.047	3.107	3.029	2.873	2.877	2.950	2.977	2.919
	Mean B	2.748	2.848	2.903	2.926		2.748	2.803	2.883	2.881	
	Factors	CD at 5%	SE (d) ±	SE (m) ±			CD at 5%	SE (d) ±	SE (m) ±		
	A	0.068	0.033	0.023			0.061	0.030	0.021		
	B	0.068	0.033	0.023			0.061	0.030	0.021		
	A X B	NS	0.066	0.047			NS	0.060	0.042		
Fruit Weight	A_0 Control	16.920	17.183	17.380	17.750	17.308	19.210	19.470	19.670	20.040	19.598
	A_1 25	17.960	18.260	18.460	18.780	18.365	20.250	20.550	20.750	21.070	20.655
	A_2 50	19.650	19.780	20.120	19.873	19.856	21.810	21.940	22.280	22.030	22.015
	A_3 75	18.960	19.223	19.247	19.480	19.228	21.120	21.380	21.410	21.640	21.388
	Mean B	18.373	18.612	18.802	18.971		20.598	20.835	21.028	21.195	
	Factors	CD at 5%	SE (d) ±	SE (m) ±			CD at 5%	SE (d) ±	SE (m) ±		
	A	0.372	0.182	0.129			0.380	0.186	0.131		
	B	0.372	0.182	0.129			0.380	0.186	0.131		
	A X B	NS	0.364	0.257			NS	0.371	0.263		

3.6 The Yield of Marketable Fruits (kg/plant)

Interactive influence of NAA and Zinc was found to be non-significant treatment of N_2Z_2 showed maximum (78.34 and 78.29 kg/plant) yield of marketable fruits closely followed by treatment N_2Z_3 (76.43 and 77.04 kg/plant). The minimum (46.01 and 48.35 kg/plant) yield of marketable fruits was presented with control (N_0Z_0) during both years of experiments. Increasing yield due to NAA or zinc sprays may be attributed to their effects on increasing levels of IAA more than increasing fruit set. Rapid fruit development and the greater mobilization of food materials from the site of production to storage organs under the influence of zinc and NAA. The present results are in agreement with the reports of Barun and Kumar [17], Saraswat et al*.,* Shukla et al*.* in litchi and Aonla. The application of zinc sulphate and NAA may have increased yield because zinc was found to be extremely beneficial in the process of photosynthesis, which mobilizes food material and accumulates quality constituents that promote physical attributes like fruit size and weight. NAA significantly reduced fruit drop and accelerated the physiological processes in the plants, both of which contributed to an increase in output.

3.7 Fruit Length

Length of fruit were significantly maximized (3.58 and 3.60cm) under treatment of N_2Z_2 (50ppm + 0.4%) followed by N_2Z_3 (3.55 and 3.52cm) over control (N_0Z_0) recorded 2.54cm and 2.62cm values respectively. The superiority in the size of fruit caused by NAA and zinc treatment might be due to its involvement in cell division and increased intracellular spaces in the parenchymal cells which could have boosted plant health and thereby increased fruit size. These findings are in line with the reports of Chaudhary et al*.* [18] in Aonla, Sahay et al*.* and Saraswat et al*.* in litchi.

3.8 Fruit Diameter

The diameter of fruit was significantly maximized (3.22cm) and (3.20cm) under treatment of N_2Z_2 (50ppm + 0.4%) followed by N_2Z_3 (50ppm + 0.6%) 3.21cm and 3.08cm over control (N_0Z_0) recorded 2.28cm and 2.40cm values respectively. The superiority in the size of fruit caused by NAA and zinc treatment might be due to its involvement in cell elongation and increased intracellular spaces in the parenchymal cells which could have boosted plant health and thereby increased fruit size. These findings are in agreement with the reports of Singh et al*.,* Saraswat et al*.* in litchi and Yadav et al*.,* in ber.

3.9 Fruit Weight (g)

NAA 50ppm and zinc 0.4% significantly increased the maximum of 20.12 and 22.28g fruit weight of litchi fruit respectively followed by treatment of NAA 50ppm and zinc 0.6% showed 19.87 and 22.03g fresh weight of fruit against control (N_0Z_0) recorded 16.92 and 19.21g values respectively. The enhancement in fruit weight due to the application of NAA might be the fact that NAA may have induced the auxin concentrations in the fruits which finally helped in the development of fruits as there is a perceptible correlation between the NAA content and fruit growth (Ghosh et al., (2009) in Aonla. These findings are by the reports of Yadav et al., in Aonla, Dutta et al. [19], Sahay et al., Saraswat et al. in Litchi.

4. CONCLUSION

Based on results obtained in the present investigation it is concluded that individual application of NAA and zinc sulphate brought about significant changes in plant metabolism. NAA 50 ppm with zinc sulphate 0.4% performed better in fruit set, fruit retention, fruit ripening, high marketable yield and maintaining the quality of litchi fruit i.e., TSS and juice content. It also minimized important desired characteristics i.e., fruit drop and fruit cracking. While the sole treatments of NAA 50ppm and zinc sulphate 0.6% showed significantly better results over other treatments. Thus, given the above achievements 50ppm NAA in consumption with 0.4% zinc sulphate may be recommended safely to the Litchi growers for increasing the quality and yield of Litchi fruits. The above recommendations adopted systematically and correctly, possess the potential improve the economy and prosperity of the country.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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